February 3, 2015

DET NORSKE VERITAS (U.S.A.), INC.
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Garrett Rhyne
Watershed Materials, LLC.
11360 Jackson Drive
The Plains, Ohio 45780

Re: Water Vapor Transmission Through Foam Bridge Materials (PP140921)

Dear Mr. Rhyne:

Det Norske Veritas (U.S.A.), Inc. (DNV-GL) was retained by Watershed Materials, LLC. (Watershed Materials) to perform testing of a foam material that is used as a spacer (bridge) between drainage tiles and pipelines. The material was tested to provide information regarding water vapor transmission (permeance) and absorption performance of the material. The testing was performed using ASTM E96, "Standard Test Methods for Water Vapor Transmission of Materials" and ASTM D570 "Standard Test Method for Water Absorption of Plastics" as a guide. The scope of work is defined in Contract DNV-GL SFA 1-UDU5FR, Rev. 0.

MATERIALS FOR TEST

Watershed Materials provided sample material, Expandable Polypropylene (EPP - Grey Foam) with film finish, for testing in accordance with Table 1. In the as-provided condition, the EPP had a film finish on all exterior facing surfaces. DNV-GL extracted test samples from the material to conform to standard specifications for size, resulting in a single face of each sample having the film finish removed.

WATER VAPOR TRANSMISSION (WVT) TEST

From the provided material, DNV-GL cut (4) cylindrical samples for WVT testing. Each of the foam samples were cut to 3 inches diameter by 1.5 inches deep. Three samples had the original film finish in tact on the face of the sample facing the water. One sample was wire cut (trimmed) to remove the film finish along the face oriented toward the water vapor such that a comparison could be made between water vapor transmission rates through the film compared with the un-filmed material. Note that the film finish was removed from the circumference of all WVT samples. The test set-up can be seen in Figure 1.

ASTM E96, *Standard Test Methods for Water Vapor Transmission of Materials,* was utilized for testing. The foam sample material was fastened to the top of a container of tap water and sealed with double sided tape so that water vapor could only permeate through the sample material. The material and container assemblies were placed in a desiccator cabinet at near 0% relative humidity (RH) and ambient temperature.

The samples were weighed periodically over 21 days. The resulting data is plotted in Figure 3.

The WVT rate was calculated as follows:

$$WVT=(G/t)/A$$

where:

G = weight change, grams (g)
t = time, hours (h)
G/t = slope of the straight line, g/h,
A = test area (cup mouth area), m^2, and
WVT = rate of water vapor transmission, $g/h \cdot m^2$.

The water vapor transmission rate of the film finish foam averaged 18.91 grams/hour*m^2. The water vapor transmission rate of the wire cut (non-film finish) foam was 29.93 grams/hour*m^2.

WATER ABSORPTION RATE TEST

From the provided material, DNV-GL cut (4) rectangular samples for Water Absorption Testing. Three samples had the original film finish in tact in all areas except the cut face. One sample was wire cut (trimmed) to remove the film finish from all faces such that a comparison could be made between the filmed and un-filmed materials' water absorption rates. Each of the foam samples were cut to 6 inches long by 2 inches wide by 2 inches deep.

The Water Absorption Rate Test ASTM D570, *Standard Test Method for Water Absorption of Plastics* was utilized for testing however the dimensions of the samples were reduced in order to conform to the standard. The foam sample material was weighed prior to testing. The foam material was placed in a container of tap water at ambient temperature. The material was fully submerged and weighted down with rubber stoppers. The material was removed from the water, patted dry and immediately weighed at incremental periods. The water absorption rate was then calculated.

The four film finish samples were immersed in solution (tap water) at ambient temperature with the cut side masked off with wax to prevent solution absorption. The wire cut (non-film finish) sample was immersed in solution without masking. All samples were weighted with rubber stoppers so that they would not float.

The samples were weighed periodically over 13 days and plotted, see Figure 7.

The Water Absorption Rate was calculated with the following equation:

$$\text{Increase in weight, \%} = \frac{\text{wet weight - conditioned weight}}{\text{conditioned weight}} \times 100$$

The water absorption rate testing showed that water was absorbed into the film finish foam at a rate of 17.8% and into the wire cut foam at a rate of 43.1%. Figures 1-5 show photographs of the test setup and samples before, during testing. Figure 7 shows results of data plotted after testing.

Any questions regarding this work should be directed to Rob Denzine at robert.denzine@dnvgl.com or 614.761.1214 x6940.

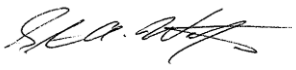
Sincerely,

for Det Norske Veritas (U.S.A.), Inc. (DNV GL)

Prepared by:

Rob Denzine
Engineer

Approved by:



Steven A. Waters
Coatings and Non-Metallics Group Leader

Table 1. Water Vapor Transmission through Foam Bridge Material Test Matrix.

Test	Spec	Material Parameters	Requirement	№ of Samples	Duration
Water Vapor Transmission	ASTM E96	Dimensions modified to conform to standard	Transmit water vapor through sample material	4	2-4 weeks
Water Absorption Rate	ASTM D570	Dimensions modified to conform to standard	Measure water absorption rate of material	4	1 week

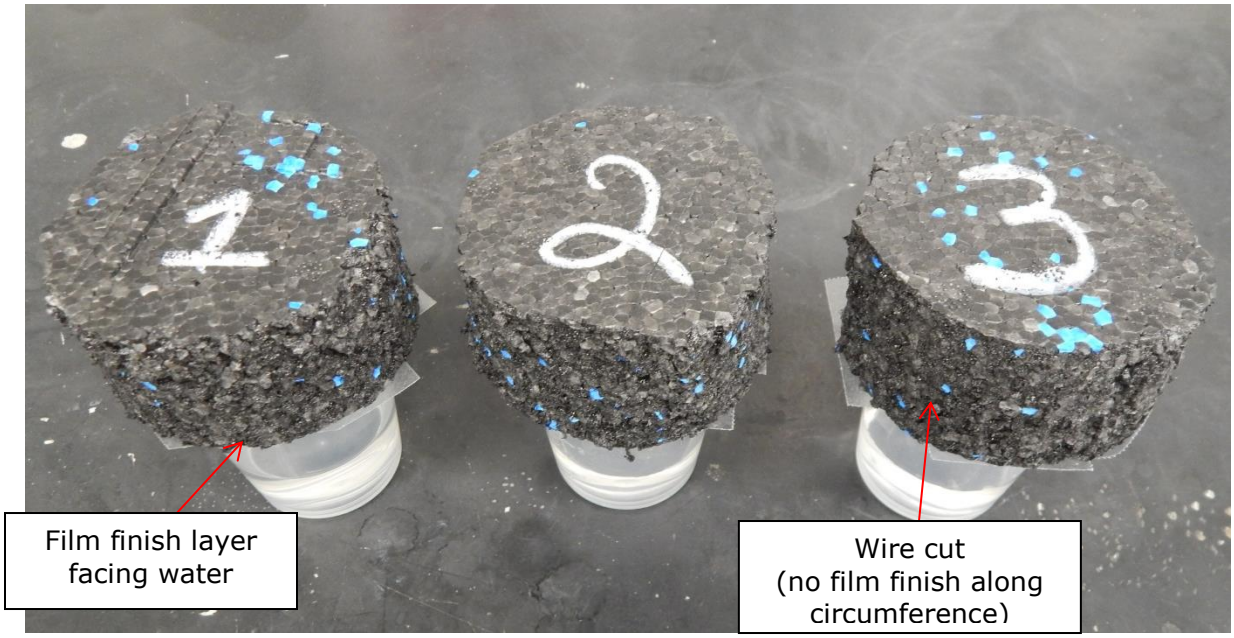


Figure 1. Water Vapor Transmission test EPP film finish samples attached with double-sided tape and attached to containers filled with tap water, prior to putting samples in 0% humidity chamber. The film finish side was oriented toward the water for the test samples. No film finish was present on the control sample (see Figure 2).

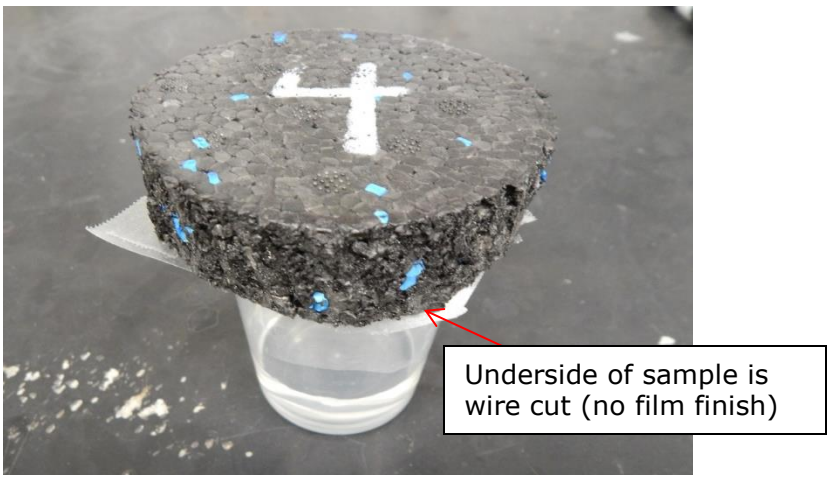


Figure 2. Water Vapor Transmission test EPP wire-cut (no film) sample attached with double-sided tape and attached to containers filled with tap water. Prior to putting samples in 0% humidity chamber.

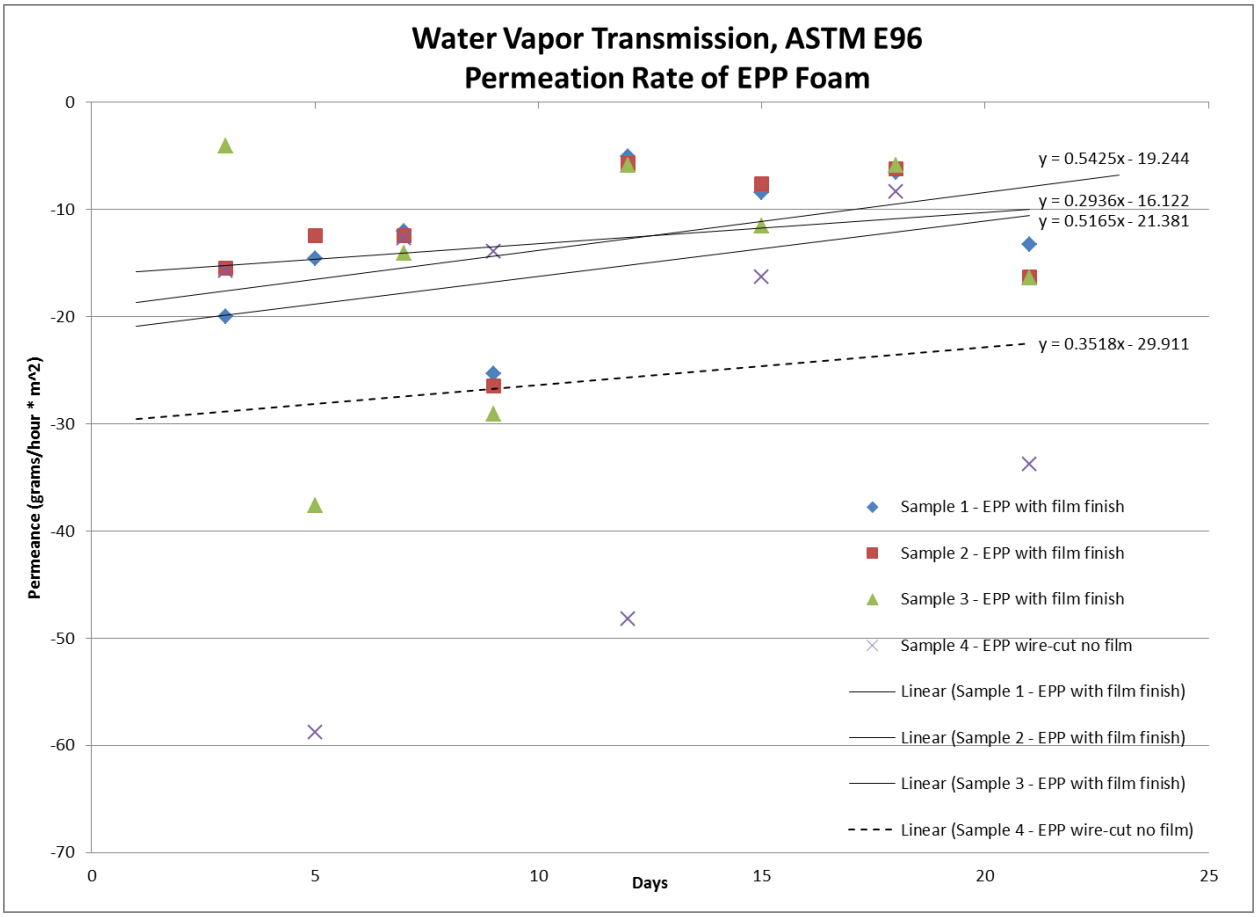


Figure 3. Water Vapor Transmission Test modified, ASTM E96. Showing permeation rate of tap water through EPP foam over 21 days.

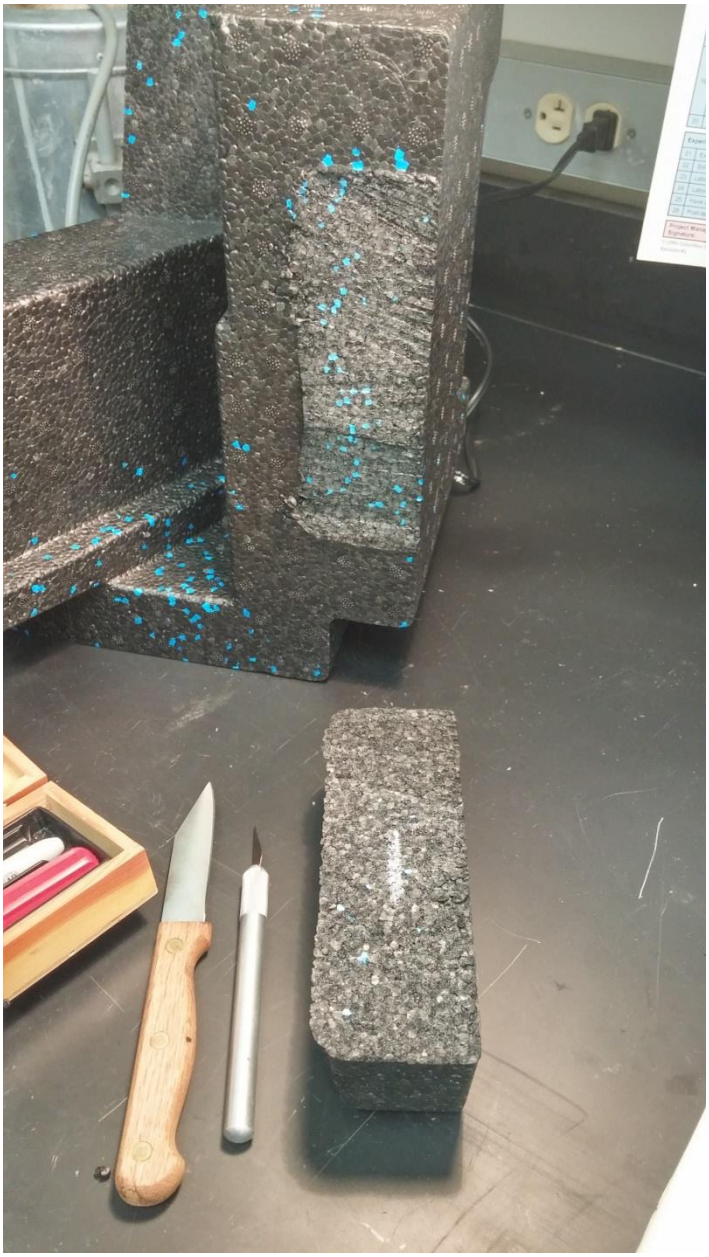


Figure 4. Water Absorption EPP film finish sample cut from larger molded sample.

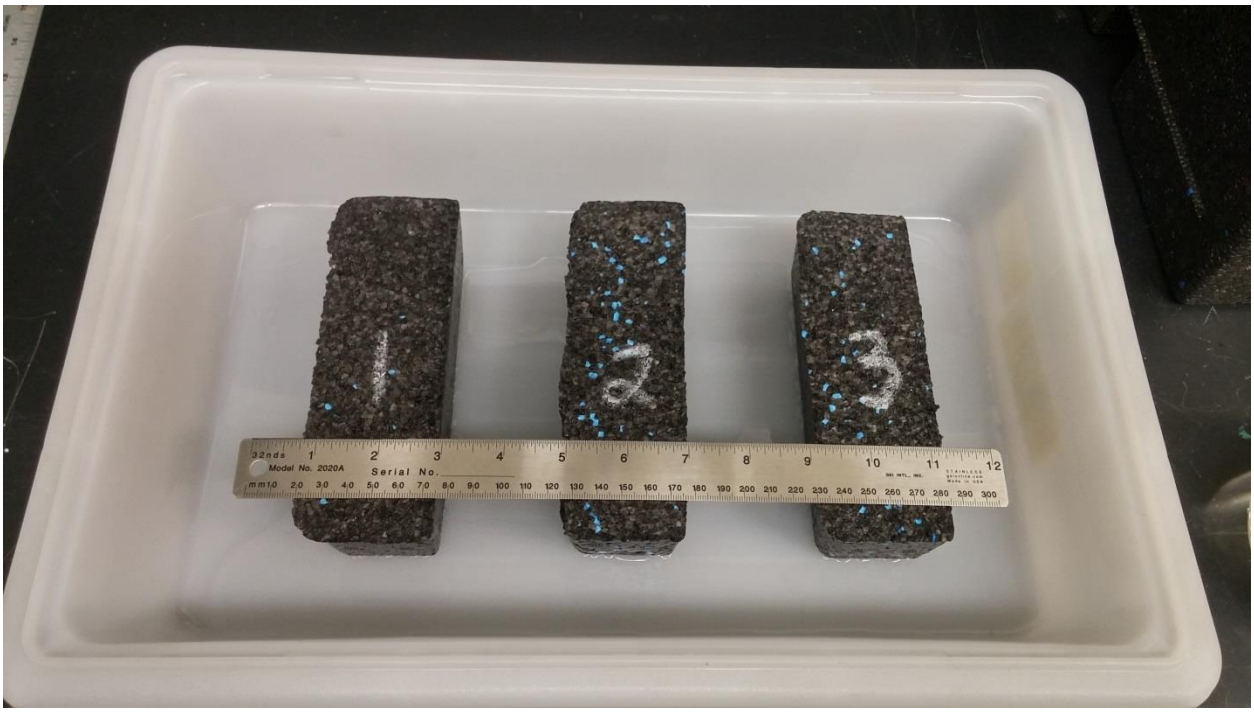


Figure 5. Water Absorption test showing EPP film finish samples prior to filling bath with tap water.

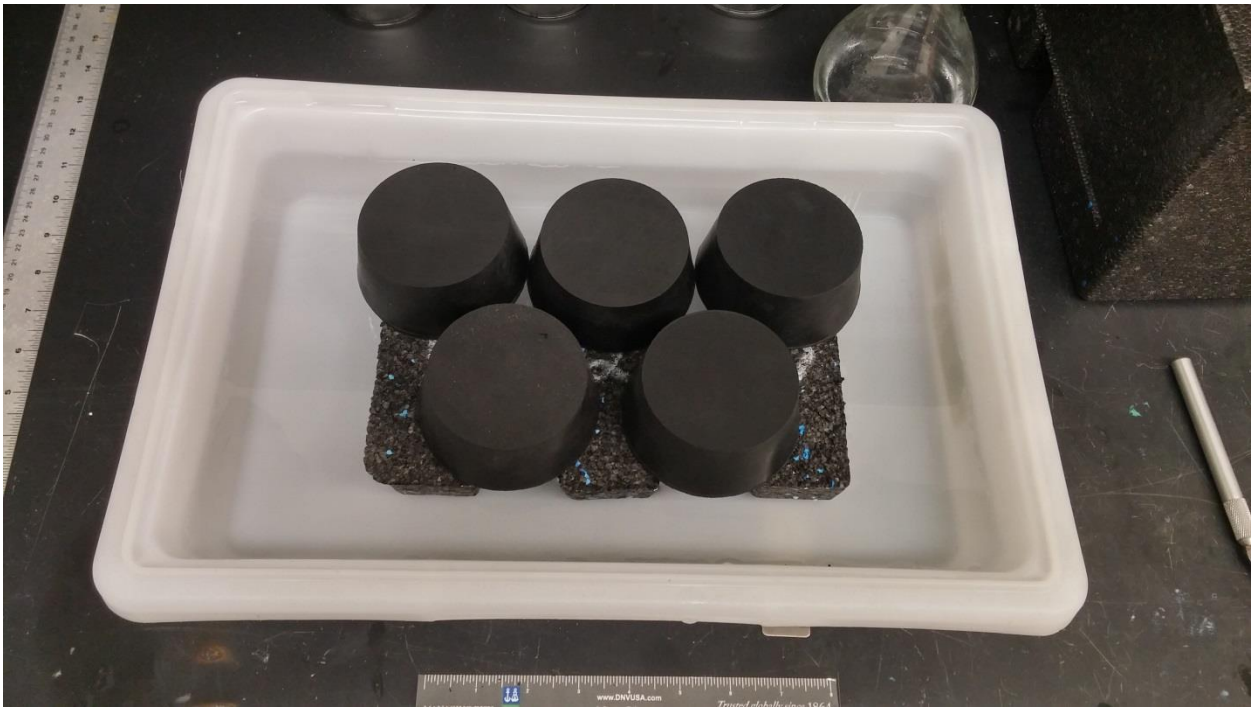


Figure 6. Water Absorption test EPP film finish samples with rubber stoppers weighing down samples to prevent floating.

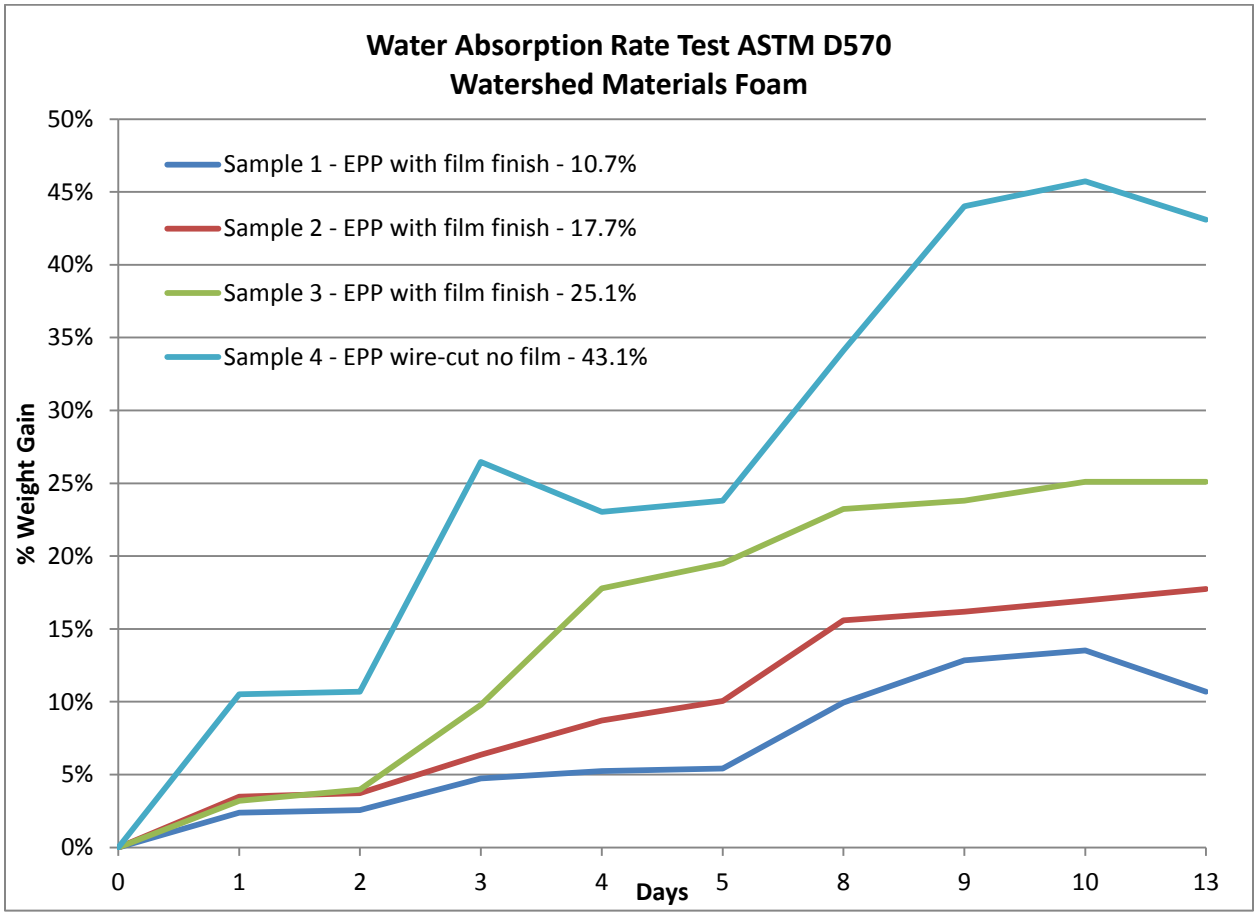


Figure 7. Water Absorption Test, ASTM D570. Showing % weight gain over 13 days.